ECONOMIC ANALYSIS: WEEDING TECHNIQUES FOR ORGANIC FARMS

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ABSTRACT

This study was undertaken to determine the benefits, detriments, and costs of the three main weeding techniques used on organic farms: soil solarization, flame weeding, and hand labor. This study will provide prospective organic farmers with useful information and economic estimates for each method.

This report shows an in depth analysis spreadsheet on the annual costs of flame weeding. The analysis was performed on a 50, 125, and 250 acre basis. The spreadsheet breaks down the ownership and operating costs for each acreage analysis. The soil solarization analysis was taken from a University of California Davis cost study. In addition, the hand labor costs per acre were taken from Tom Willey, owner and operator of TD Willey Organic Farms in the San Joaquin Valley, California. The costs of each method were broken down and put into a chart to clearly show the final economic analysis.

It was proven that flame weeding is a substantially more cost effect method than that of soil solarization and hand labor. Hand labor proved to be by far the most expensive method. Per acre costs of flame weeding were as low as $76.00. Soil solarization costs approximately $600 per acre and hand labor costs about $2,500 per acre. The approximate total costs for soil solarization and flame weeding are, respectively, $30,000 and $13,179. Those costs trend to roughly that ratio when analyzed on a 125 and 250 acre basis.

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CHAPTER 1

INTRODUCTION

Over the past few years, many farms have been making the shift to organic farming due to sustainability efforts, the non-use of pesticides, and economic benefits. The growing trend of purchasing organic fruits and vegetables has introduced specialty stores and sections in supermarkets dedicated to this new wave of agricultural marketing. Organic weed control is one of the many problems that organic farmers must confront. Weeds are a serious problem in agriculture production worldwide and were estimated to cause an annual global crop loss of 12.2% in 2002 (Agrios 2005). The National Organic Program (NOP), in conjunction with the USDA, provides strict guidelines for organic farmers to follow in order to be certified organic. Organic farms cannot use herbicides or fumigation techniques that conventional farms use in order to control weeds. There are a variety of methods used on organic farms. Wilson (2007) found that flame weeding (see flame weeding in literary review), also called flame cultivation or flaming, is a thermal physical control method that is part of the NOP under the organic foods production act of 1990. Furthermore, an additional thermal weed control technique is soil solarization. Soil solarization utilizes a clear polyethylene (plastic) sheet which purifies the soil. Schonbeck (2009) found that soil solarization, another thermal weeding technique, kills emerging weeds, some soil borne crop pathogens, insect pests, and weed seeds. The third, most labor intensive method of weed cultivation is hand weeding. Due to the current economic

downturn and water shortages that California is suffering, organic farmers will continue to search for the most costs effective method of weed cultivation.

Problem Statement

What are the benefits and detriments of each method? What method will be the most cost effective and will certain benefits of a method offset possible extra costs?

Hypothesis

Due to high labor hours required to weed an acre, the hand labor process will be the most expensive. Flame weeding will provide field availability, cost effectiveness, and most efficient use of labor hours, thus proving it to be the most beneficial weed cultivation method. Soil Solarization will be less expensive than flame weeding with climate being the deciding factor.

Objectives

1. To obtain and assess costs associated with flame weeding, soil solarization, and flame weeding.
2. To analyze the benefits and detriments of flame weeding, soil solarization, and flame weeding.
3. To evaluate total economic costs for flame weeding, soil solarization, and hand labor on a 1, 50, 125, and 250 acre basis.

SIGNIFICANCE OF STUDY

Organic agriculture's acreage demand is increasing year by year. According to the 2007 Census of Agriculture, California has the most acres with 368,934 acres of organically farmed land and 3,515 farms in the United States (In addition, there were 60,051 acres in 2007 in the process of being converted from a conventional to organic farm). California organic farm's revenue topped $656 million (2007 Census of Agriculture, 2007). Weeding farms labeled "Organic," do not require resources that may be imperative on a conventional farm. Without the use of herbicides and pesticides, resources such as diesel, liquid propane, and labor rates are imperative to weed management on organic farms. Soil solarization costs on an average of $150 to $300 dollars per row of crop application in a warm climate (Stapleton, et al. 2005). In addition, according to the Natural Propane Gas Association it costs about $3.50 per acre per application to flame weed (2002). Depending on the farm and current economic conditions, costs of labor will vary. Finding the most economically effective method of weed cultivation techniques, will provide the increasing number of organic farms a more cost effective approach as well as knowledge on the processes, benefits, and detriments of the three methods studied.

CHAPTER 2

LITERATURE REVIEW

In past decades, large numbers of farms have been making the change from conventional to organic farming. One of the biggest problems on farms is weed control, which is due to weeds competing with crops for sunlight, water, and nutrients. If weeds become too intrusive, they will decrease crop production, leading to reduced profits. During the transition from conventional to organic farming, organic farmers cannot use chemicals to suppress weeds and therefore must utilize other techniques of weed control. The three main methods of weed control utilized on organic farms are: soil solarization, flame weeding, and hand labor.

Soil Solarization

Soil solarization is a technique used for purifying soil and suppressing weed growth. Solarization involves trapping heat from the sun under a transparent polyethylene (thin plastic) sheet (mulch). It is necessary to have hot temperatures when soil solarization is performed; the minimum average temperature per day should be 95° Fahrenheit (35°C). Therefore, soil solarization is usually performed in the summer (Stapleton, et al. 2000). Solarization is useful in controlling parasitic weeds and certain annuals, but it is not effective against perennials (Jacobsohn, et al. 1980). The field selected for solarization should have abundant sunlight and no shade. For the best results, the field should be plowed and leveled before application of the polyethylene cover mulch. After leveling, the soil needs to be moistened fifteen to twenty centimeters deep. Once the soil is moistened, one must apply the clear polyethylene mulch with

either a machine (main method) or by hand (usually on smaller plots of land). The mulch must be sealed at the edges for solarization to be fully effective. During the first three to four weeks, water droplets should form on the inside of the mulch, and the mulch should be hot to the touch (Abu Sayed and Malakar, 2004). This technique is an easy and inexpensive way to produce healthy, disease-free soil without the use of chemical application.

Advantages and Disadvantages of Soil Solarization

There are many advantages of soil solarization, the biggest being cost-effectiveness, with a transparent polyethylene sheet being the main material used. Soil solarization requires fewer seeds due to the higher germination rate. The seedlings are healthy and vigorous due to the disease and pest free soil. In addition, crop production is improved (Abu Sayed and Malakar, 2004). In a study performed by Abu Sayed and P.K. Malakar (2004), it was found that rice grain and vegetable produce were larger in size and more attractive to the consumer, along with a production increase of twenty to thirty percent. In addition, soil solarization presents no dangerous or hazardous substances to surrounding plants or people. After solarization has completed, the clear polyethylene mulch can also be used as a bed mulch (as a foundation for the subsequent crop) to improve the cost/benefit ratio (Stapleton, et al. 2005).

Given the advantages, there are few disadvantages to soil solarization. The thin polyethylene mulch can have the tendency to rip in certain spots. If the mulch rips, it will let out moisture and heat, which are necessary to the success of solarization. Sealing the rip with plastic tape will easily remedy any rips that occur (Sayed and Malakar, 2004). The overwhelming amount of advantages over the minimal disadvantages makes soil solarization an attractive choice for organic farmers that live in temperate climates.

Previous Studies

Standifer, Wilson, and Rhonda Porsche-Sorbet (1980) performed four studies to test the efficiency of soil solarization as well as the effectiveness of clear and black polyethylene mulches. The studies were conducted over a three year period with treatment times of up to twelve weeks. Soil samples up to fifteen centimeters deep were taken after the treatment, to test for seed germinations (1984). Horowitz, Roger, and Herlinger (1983) found that mulching for two to four weeks effectively controlled only annual weeds, but, some weeds deeper than ten centimeters, such as *Avena sterilis*, were not affected by solarization (1983). The first study found that soil solarization diminished weed growth in Annual bluegrass, with Barnyard grass being the most resilient to solarization. Barnyard grass was the most resilient of the three, having six germinated seeds in the three to four centimeters of soil depth. Another weed is annual sedge, where the first germinated seed was three to four centimeters deep, opposed to annual bluegrass, having its first germinated seed four to five centimeters deep. Study two strictly concentrated on how annual sedge and dayflower were affected by a clear mulch treatment. The first germinated annual sedge seed was in the four to five centimeter depth. Furthermore, dayflower's first germinated seed was in the eleven to twelve centimeter depth. Study two proved that soil solarization is extremely effective against dayflower. Given that most annual weeds only germinate within the top one to two centimeters of the soil, solarization proves to be an effective form of weed control (Standifer, Wilson, and Porsche-Sorbet. 1984).

Flame Weeding

Flame weeding in agriculture dates back to 1852, but was not considered an effective weed control method until the 1940's (Cohen 2006). By 1965, there were approximately twenty-five thousand flame weeders in commercial agriculture use. When herbicides and pesticides became popular in the late 1960's, flame weeding usage dropped significantly. In the early 1990's, flame weeding was only implemented on approximately ten thousand acres in the United States. Flame weeding does not actually "burn" the weed, instead the intense heat expands the cell sap which damages the cell walls and prevents water movement in the weed, eventually killing it. After the flaming application, the weed will sag if it is dead (Cohen 2006).

The two types of flame weeders are hand-held and row-crop weeders. Hand-held flame weeders come with a wand, hose, and propane tank. The tank is usually carried on a dolly or in a backpack while the worker handles the wand (used for pricing purposes). According to the *Journal of Pesticide Reform*, hand held flame weeders can cost up to one-hundred dollars (Cohen 2006). The other method of flame weeding is using a row-crop flamer. The row-crop flame weeder is pulled by the tractor through the field. Depending on stage of weed growth, the burner operating pressure can range from 170kPa (kilopascal) to over 485kPa and can travel on average between one and four miles per hour (Lague, Gill, Lehoux, Peloguin 1997). Flamers have been built for $1,200 for an eight-row unit (Anon 1993) and $1,520 for a 12-row unit (Houtsma 1991). Commercial kits cost around $1,900 (the price for an eight-row from Thermal Weed Control Systems). These kits do not include hoses, a tank, or a tool bar. It is more cost-effective for growers to pick up these items locally from a gas dealer or salvage operation." Row crop flame weeders perform best when used in warm, dry, and windless conditions. The soil should be leveled well so small weeds cannot hide in the uneven soil (Barr 1947, Parish, Porter, Vidrine

1997). When used in the right conditions, flame weeding can be an extremely effective method of weed control.

Advantages and Disadvantages of Flame Weeding

The main advantage of hand-held flame weeding is the ability to weed more rapidly than hand-weeding. In addition, hand-held flaming is performed standing up, which is easier on the body, cutting down on the amount of time needed bent over hoeing or hand-weeding (Cohen, 2006). Flame weeding delays the presence of weeds in crop beds by killing the weeds present before the crop has breached the soil. This can significantly reduce hand-weeding labor costs (Wilson 2007).

Some disadvantages of hand-held flame weeders include the heavy, bulky propane tank that is carried or pulled around. In addition, if hand-held flaming on a large farm, the process can be long and tiresome (Cohen 2006). The advantages of using a row-crop flame weeder outweigh a hand-held flame weeder from a standpoint of labor, time, and cost. Jennine Wilson (2007) states that "Row crop flame weeding is more economical because it targets only the area along the seedbed where the crop actually grows." Row-crop flaming may be as efficient depending on the size and amount of weeds. Hand-held is usually more efficient due to the worker *seeing* the weeds to flame as opposed to a worker operating a tractor while flaming eight to twelve rows at a time, but as mentioned above, the time and costs are greater when operating hand-held flame weeders.

Previous Studies

A 1998 study performed by Ascard, a professor in Sweden, studied the effectiveness of different burn angles on a flame weeder. The flame weeder was tested at five different angles towards the ground: forty-five degrees and sixty-seven degrees aimed forwards and backwards, and ninety degreed straight down. The burner that was angled sixty-seven degrees backwards gave the highest weed reduction results, but there were no significant differences between the five angles tested. There were significant temperature differences between the different angles, but the differences did not show any correlation between temperature and flaming effectiveness (Ascard 1998).

Hand-weeding

The most basic method of weeding is by hand. Hand-weeding is very time consuming, physically demanding, and not cost efficient for a farmer. Hand hoeing along with the use of precision hand-weeding tools are the easiest methods of hand-weeding because it is less physically demanding. According to Nalewaja (1999), hand pulling weeds is a means of preventing the development and spread of resistant weeds in the field. The practice is effective but is not practical for large crop fields.

Advantages and Disadvantages

The main disadvantage to hand-weeding is the cost. In a study done by Steven Winter and Allen Wiese, they found that hand-weeding sugar beets was the most expensive method. However, Winter and Wiese (1982) were comparing hand-weeding (hoeing) to chemical uses. The costs for hand-weeding one hectare (2.47 acres) were found to be $1,077. The next cheapest method used was one-fifth of the cost of hand labor (1982). Furthermore, one can assume that the price today would be at least twice as much, given the study was performed in 1992.

Summary

Soil solarization purifies soil by trapping heat under a clear polyethylene sheet. In previous studies performed it has proven to be a very effective means to control weeds. On the other hand, flame weeding is another effective way to reduce weed amounts, delay weed growth, and reduce labor costs. Hand-weeding is effective and practical on small scale farms but is too expensive and impractical on large scale farms.

CHAPTER 3

METHODOLOGY

Procedure for Data Collection

The three methods of weeding to be studied: soil solarization, flame weeding, and hand labor. The main method of obtaining the information needed to determine the costs per acre of soil solarization is by contacting various farmers of California and getting an approximate prices of each method. Given that soil solarization must be performed in hot climates, the main focus of the study will be on farmers in the San Joaquin Valley. The information needed to perform the soil solarization cost analysis are:

- Red diesel price per gallon
- Cost of mulch per acre
- Labor hours and labor costs needed to install mulch and maintain mulch during the solarization process.

Many of the initial costs for flame weeding can be found by contacting Flame Engineering (LaCrosse, Kansas), the biggest flame weeding manufacturer in the United States. There are two main types of flame weeders: a hand-held and row-crop flame weeder. The main costs for flame weeding are:

- Liquid propane costs (Source variable with time)

- Liquid propane consumption per acre (different depending on flame weeder) (Source variable with time)
- Flame weeder costs (propane tanks and flame weeder) (Source variable with time)
- Labor costs (per hour) (Source variable with time)
- Time requirement to flame weed one acre (with row-crop flame weeder and hand-held flame weeder) (Observed estimate)

Hand labor is one of the traditional ways of weeding an organic farm. Data collection for hand labor will be gathered from various organic farmers.

Hand labor costs:

- Labor costs (per hour)
- Labor hours (man hours) to hand weed one acre

Procedures for Data Analysis

Soil Solarization:

Diesel costs/acre + Mulch costs + Labor costs

Labor costs: Labor hours x Labor rate

Diesel costs: If provided with *only* the time it takes to solarize and the price of diesel, refer to Diesel Consumption Costs per Hour below.

Flame Weeding:

Row-crop method:

Diesel consumption/acre + Liquid Propane costs/acre + Labor Costs + Row-crop flame weeder costs

Labor costs: Labor hours x Labor rate

Hand-held method:

Liquid Propane costs/acre + Labor Costs + Hand-held flame weeder cost (propane tank and flame weeder)

Labor costs: Labor hours x Labor rate

Hand Labor:

Labor costs: Labor hours x Labor rate

Diesel consumption costs per hour:

Variables Used: Horsepower and Diesel Costs

.044 x Horsepower = gallons of fuel per hour.

Example: Tractor with 51 hp with $3.50 diesel price

.044 x 51 = 2.24 gallons of fuel per hour

2.24 x $3.50 = $7.84/hour

Assumptions

This study assumes normal weather in the San Joaquin Valley. In the cost analysis it will be assumed that the tractor(s) needed for flame weeding and soil solarization will already be owned by the farmer.

Limitations

The methodology developed will be meaningful for studies in the United States, but the results will be significant to the San Joaquin Valley, specifically. Labor rates vary throughout the United States. The results may seem inaccurate to a farmer outside of the San Joaquin Valley if the labor rates differ. Soil solarization can only be implemented in certain climates; therefore, the soil solarization analysis may not be useful to other regions of the United States.

CHAPTER 4

DEVELOPMENT OF STUDY

The analysis and overall purpose of the study is to determine the most cost effective weeding technique(s) for organic row crop farmers. The techniques that have been studied are: flame weeding, soil solarization, and hand labor.

The data collected for flame weeding was mainly taken from Steve from Flame Engineering. The list price of the utility tractor was taken from tractordata.com. Given that flame weeding is most effective when used before every growing season, the assumption of three growing seasons per year was taken. After collecting and calculating all of the basic, operating, and ownership costs of the flame weeder, the data was inputted into a spreadsheet similar to that of the Farm Management text book (2007, Kay, Edwards, and Duffy). The basic data consists of the list price of the flame weeder and tractor, ownership life of the flame weeder, estimated annual use of the flame weeder and tractor, and the price of fuel used for the equipment (propane for the flame weeder and red diesel for the tractor). The ownership costs included the capital recovery method and the taxes, insurance, and housing of the flame weeder and tractor. The operating costs included the estimated repair costs of the flame weeder and tractor, fuel costs, lubrication and filter costs for the tractor, and labor costs. Once the annual data was inputted into the spreadsheet, finding the cost per hour and cost per acre yielded the final results. Once the cost per acre and cost per hour were calculated, they could then be compared to the soil solarization and hand labor costs per acre.

Flame Weeding Startup Costs
8 Row Flame Weeder
Tri-Annual Pre-emergent Use (50 Acres)

Basic Data	
List Price (John Deere 5065M two wheel drive utility tractor)	$35,603.00
List Price (flame weeder)	$12,000.00
Ownership Life (flame weeder)(hrs)	1500
Estimated Annual Use (tractor)(hrs)	37.5
Estimated Annual Use (flame weeder)(hrs){(50ac./4ac.perhr)x2}	37.5
Annual acres (50 x 3)	150
Price of fuel per gallon ($)(propane)	$1.90
Price of fuel per gallon ($)(red diesel)	$1.75
Calculate Ownership Costs	
Capital Recovery Method (12,000 x .12590 (7% int rate, 12 years)	$1,510.80
Taxes, insurance, and housing (1.5% x $12,000)(flame weeder)	$180.00
Taxes, insurance, and housing (1.5% x $35603)(tractor)	$534.05
Total annual Ownership Costs	$2,224.85
Ownership Costs per hour	$59.33
Ownership Costs per acre (2224.85 ÷ 150)	$14.83
Calculate Operating Costs	
Repairs (tractor)(.2075 x 35603 x 37.5 ÷ 100)	$2,770.36
Repairs (flame weeder)(1.1675 x 12000 x 37.5 ÷ 100)	$5,253.75
Diesel Fuel (2.86 x $1.75 x 37.5)	$187.69
Propane ($58.90 x 37.5)	$2,208.75
Lubrication and Filters (tractor)	$28.15
Labor (Labor costs per hour x Hours)	506.25
Total annual operating costs	$10,954.95
Operating costs per hour	$292.13
Operating costs per acre (10954.95 ÷ 150)	$73.03
Calculate total cost per hour	
Ownership cost per hour	$59.33
Operating cost per hour	$292.13
Total annual costs	$13,179.79
Total cost per hour	$351.46
Calculate cost per acre	
Performance rate: 4 acres per hour ($381.13 ÷ 4 acres)	$87.87

Flame Weeding Startup Costs
8 Row Flame Weeder
Tri-Annual Pre-emergent Use (125 Acres)

Basic Data	
List Price (John Deere 5065M two wheel drive utility tractor)	$35,603.00
List Price (flame weeder)	$12,000.00
Salvage Value (flame weeder)	$0.00
Average Value (flame weeder)	$6,000.00
Ownership Life (flame weeder)(hrs)	1500
Estimated Annual Use (tractor)(hrs)	93.75
Estimated Annual Use (flame weeder)(hrs){(50ac./4ac.perhr)x2}	93.75
Annual acres (125 x 3)	375
Price of fuel per gallon ($)(propane)	$1.90
Price of fuel per gallon ($)(red diesel)	$1.75
Calculate Ownership Costs	
Capital Recovery Method (12,000 x .12590 (7% int rate, 12 years)	$1,510.80
Taxes, insurance, and housing (1.5% x $12,000)(flame weeder)	$180.00
Taxes, insurance, and housing (1.5% x $35603)(tractor)	$534.05
Total annual Ownership Costs	$2,224.85
Ownership Costs per hour	$23.73
Ownership Costs per acre (2224.85 ÷ 375)	$5.93
Calculate Operating Costs	
Repairs (tractor)(.2075 x 35603 x 93.75 ÷ 100)	$ 6,925.90
Repairs (flame weeder)(1.1675 x 12000 x 93.75 ÷ 100)	$13,134.38
Diesel Fuel (2.86 x $1.75 x 93.75)	$469.22
Propane ($58.90 x 93.75)	$5,521.88
Lubrication and Filters (tractor)	$70.38
Labor (Labor costs per hour x Hours)	1265.625
Total annual operating costs	$27,387.37
Operating costs per hour	$292.13
Operating costs per acre (27387.37 ÷ 375)	$73.03
Calculate total cost per hour	
Ownership cost per hour	$23.73
Operating cost per hour	$292.13
Total annual costs	$29,612.22
Total cost per hour	$315.86
Calculate cost per acre	
Performance rate: 4 acres per hour ($315.86 ÷ 4 acres)	$78.97

Flame Weeding Startup Costs
8 Row Flame Weeder
Tri-Annual Pre-emergent Use (125 Acres)

Basic Data	
List Price (John Deere 5065M two wheel drive utility tractor)	$35,603.00
List Price (flame weeder)	$12,000.00
Salvage Value (flame weeder)	$0.00
Average Value (flame weeder)	$6,000.00
Ownership Life (flame weeder)(hrs)	1500
Estimated Annual Use (tractor)(hrs)	187.5
Estimated Annual Use (flame weeder)(hrs){(50ac./4ac.perhr)x2}	187.5
Annual acres	750
Price of fuel per gallon ($)(propane)	$1.90
Price of fuel per gallon ($)(red diesel)	$1.75
Calculate Ownership Costs	
Capital Recovery Method (12,000 x .12590 (7% int rate, 12 years)	$1,510.80
Taxes, insurance, and housing (1.5% x $12,000)(flame weeder)	$180.00
Taxes, insurance, and housing (1.5% x $35603)(tractor)	$534.05
Total annual Ownership Costs	$2,224.85
Ownership Costs per hour	$11.87
Ownership Costs per acre (2224.85 ÷ 750)	$2.97
Calculate Operating Costs	
Repairs (tractor)(.2075 x 35603 x 187.5 ÷ 100)	$13,851.79
Repairs (flame weeder)(1.1675 x 12000 x 187.5 ÷ 100)	$26,268.75
Diesel Fuel (2.86 x $1.75 x 187.5)	$938.44
Propane ($58.90 x 187.5)	$11,043.75
Lubrication and Filters (tractor)	$140.77
Labor (Labor costs per hour x Hours)	2531.25
Total annual operating costs	$54,774.75
Operating costs per hour	$292.13
Operating costs per acre (54774.75 ÷ 750)	$73.03
Calculate total cost per hour	
Ownership cost per hour	$11.87
Operating cost per hour	$292.13
Total annual costs	$56,999.59
Total cost per hour	$304.00
Calculate cost per acre	
Performance rate: 4 acres per hour ($309.93 ÷ 4 acres)	$76.00

The data collected for soil solarization were extracted from an article on Tom Willey, an organic farmer from Fresno County, and a UC Davis cost study. Willey began weeding his organic farm using hand laborers, costing $2,000 to $3,000 per acre (2005, UC IPM Online). Once Willey switched to soil solarization, he saved 80% (Assuming $2500 average hand labor cost per acre) on weeding costs per acre, costing approximately $500 per acre (2009, May 18, Interview). In addition, a UC Davis cost study calculated solarization and weeding costs per acre:

Bed Width (cm)	**No. rows/bed**	**Unsolarized**[1]	**Unsolarized + DCPA**[1]	**Solarized**[2]
75	1	1772	1029	35+600= 635
100 ~ 40 inches	2	2323	1116	45+550= **595**
100 ~ 40 inches	4	2609	1627	153+550= 703
150	2	1394	836	56+500= 556
150	4	1832	1352	36+500= 536
150	6	2953	1089	50+500= 550

The hypothesis inevitably suggested that flame weeding would be the best overall, cost effective method, opposed to soil solarization and hand labor. The objectives for the study included obtaining and assessing costs of each method along with the benefits and detriments of each method. The costs were then implemented on a 1, 50, 125, and 250 acre basis to show variation. Once all of the analytical data was collected the costs for each method were compared and analyzed. The hypothesis was tested by comparing the data collected for hand labor, soil

[1] Hand weeding the beds plus cultivation of furrows. DCPA (Dacthal pesticide) applied at 10 lbs/acre preplan incorporated.
[2] Hand weeding plus polyethylene

solarization and flame weeding. The hypothesis suggested that soil solarization would be the most cost effective weeding technique. The following tables prove the hypothesis to be false. Hand labor was by far more expensive than flame weeding and soil solarization. Although soil solarization only needs to be performed once a year, the costs per acre are more than six times as much as the flame weeding costs per acre. The following charts prove the hypothesis:

	Hand Labor	Soil Solarization	Flame Weeding[3]		
			50 ac.	125 ac.	250 ac.
Ownership Costs per ac.			$14.83	$5.93	$2.97
Operating Costs per ac.			$73.03	$73.03	$73.03
Total Costs per ac.	$2,500 approx.	$600 Approx.	$87.87	$78.97	$76.00

Total Costs (approx.)	Hand Labor	Soil Solarization	Flame Weeding[4]
50 ac.	$125,000	$30,000	$13,179.79
125 ac.	$312,500	$75,000	$29,612.22
250 ac.	$625,000	$150,000	$56,999.59

[3] The study assumes flame weeding three time per year (ex. 50 acre farm would yield 150 acres of flame weeding)
[4] Price of the flame weeder not included (ownership and operating costs only)

CHAPTER 5

SUMMARY AND CONCLUSION

The study examines three primary methods of weeding an organic farm. The three methods studied were hand labor, soil solarization, and flame weeding. The benefits and detriments of each method were studied to see if any had major effects on costs. The fact that soil solarization is performed only once per year (summer months) means that farmers only forgoe weeding expenses once per year. For farmers in a temperate, soil solarization friendly climate, the single weeding cost per year may be enticing, but is still more expensive than flame weeding. In addition, the costs of performing each method were analyzed to determine the most cost effective method of weeding. The hypothesis suggested that due to high labor hours required to weed an acre, the hand labor process will be the most expensive. Flame weeding would provide field availability, cost effectiveness, and most efficient use of labor hours, thus proving it to be the most beneficial weed cultivation method. Soil solarization is less expensive than flame weeding with climate being the deciding factor. Chapter four's tables prove the hypothesis to be false. Flame weeding was the most cost effective weeding technique.

This study will provide accurate estimates to organic farmers looking into different and/or more cost effective methods to weeding. For cost efficiency purposes, it is recommended to use flame weeding. If variable factors permit the use of flame weeding, soil solarization is the next cheapest method. Farmers must remember that although flame weeding and hand labor can be used in almost all climates, soil solarization is limited to very warm temperate climates. In

conclusion, this study will provide farmers with accurate costs, along with the knowledge that a farmer will need when utilizing hand labor, soil solarization, and flame weeding to weed their organic farm.

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APPENDIX

Acre - 208' x 208' (2496" x 2496")
Row Seperation - 40" (assumed)

Acres per Hour calculation

Number of Rows (2496"/40")	62.4	rows	~62
8 Row Flame Weeder (62/8)	7.75	~8 passes	

208' x 8 passes = 1664'
1664'/5280' = .32 miles
Average Speed = 4 mph
.32/4 = .08
.08 x 60 = 4.8 minutes (4:48)
Allowance of 1 minute for the 7 180° turns.
7 + 4:48 = 11:48 (**12:00**)
Assume approximately 4 acres per hour.

Gallons of diesel per hour (.044 x 65 = **2.86**)

Consumption per acre (propane)(4 acres per hour, approximately using 7.75 gallons per acre)
Price per hour = $58.90